RISK AND LARGE-SCALE RESOURCE VENTURES

Horst Siebert

WP #1816-86

RISK AND LARGE-SCALE RESOURCE VENTURES

Horst Siebert

WP #1816-86

Risk and Large-Scale Resource Ventures

Horst Siebert*

Large-scale resource ventures are characterized by high set-up costs, a gestation period of five, seven or ten years and a long period of operation in which the benefits of a project come in. Very often, large-scale ventures require an innovation in technology such as the development of offshore-oil platforms and exploration, drilling, and transportation under arctic conditions. Moreover, environmental impacts may occur, and in some cases, irreversibilities may exist in the competing uses of nature. Finally, private and social benefits may diverge. Future benefits must be weighed against the initial costs, with benefits occurring at a later date and being discounted. Benefits and some of the costs are uncertain. Risk relates to the technology, to initial, operating and closing costs, to environmental disruptions, to price and revenue and from a private firm's point of view to changes in taxation, regulation or even expropriation. All these different types of risk account for the possible outcome that the huge initial financial outlays may be lost, i.e. the different types of risk make up financial risk.

In this paper we look at the role of risk in large-scale projects. At the outset, risk is defined and different types of risk for large-scale projects are described. We then discuss

the impact of risk on the profit of a mine when we consider a single agent who is owner and sponsor at the same time. We then analyze approaches to risk management and risk shifting when a second agent is introduced. If we allow for more than two agents and for different types of risk, risk allocation can be described as complex net of contractual arrangements. Finally, some limits of risk shifting are pointed out.

The meaning of risk

Risk means that the implications of a decision cannot be determined ex ante. Variables affecting a decision such as product or factor prices or technological relationships are random, i.e. the occurance of a specific value of a variable depends on a state of nature which cannot be controlled by an individual agent. The variables of interest to the agent diverge from a mean on both sides with the mean being defined as the expected result or as the mathematical variance of possible results. Normally, it is assumed that the agent can attribute probabilities to a variety of outcomes, i.e. he or she knows a density function for the random variables. Probabilities assigned to the variables may be based on objective observations, such as past experience or a multitude of observations, or they may reflect personal judgements.

The variance of a specific variable may be relevant to one agent, but not to another. Consequently, risk can only be defined with respect to the objective function of an agent. The variance of the price of a natural resource may mean a different risk for a resource-extracting firm or for a consumer; or it implies different risks for producers with a diverging risk attitude. Moreover, the relevance of a variance in a specific variable depends on the set of constraints of an agent. A given variance in the price of a natural resource has a smaller risk for a country, if the country not only exchanges the resource against consumption goods but if it has accumulated financial assets. Or assume that a resource country uses part of the resource in production at home. Then the probability of a fall in the resource price will hit the country's export earnings, but industrial activity at home may be stimulated due to lower resource prices. In the capital asset pricing model, the relevance of the constraint set for the definition of risk is pointed out by the fact that the relevance in the variance of a specific variable depends on the portfolio of an agent. More specifically, the risk of an investment (an asset or more generally of an economic decision) is measured not by the variance of income or profit from the specific investment but the variance of income from the portfolio caused by that investment. Risk is primarily dependent on the covariance of the return to the specific investment with the return to the total investment of a portfolio. For instance, a fire insurance has an uncertain outcome the payment varying between the value of the houses in the case of fire and

zero (Lind 1982, p. 60). But this risky investment makes the overall portfolio more certain.

The variance of a variable may not be especially relevant for an individual agent due to options of shifting the risk within the given set of restraints. More important is that the risk of an individual agent may be shifted to someone else for whom the variance in a variable does not present such a risk. A variance with weight in the tail for a falling price of a natural resource represents a risk for a resource-exporting country, but a similarly skewed probability distribution is an insurance to a resource-importing country. The shifting of risk therefore is an important method of risk reduction. Institutional arrangements of risk sharing are of utmost importance for risky projects. Risk, however, can only be shifted if the variance of a variable implies different risk for different agents. This no longer hold for risk relating to public goods, i.e. social risk. If the variable in question is a public good like air quality, variance in that variable "must be consumed in equal amounts by all" (Samuelson 1954) and risk cannot be shifted.

The analysis of the impact of risk overlaps with the discounting of future benefits and costs. As a rule of thumb, the existence of risk requires a risk premium in addition to the discount rate thus making a project less profitable. But this rule only relates to risky benefits whereas risky future costs require a substraction of the interest rate, and the rule only holds under very

specific assumptions (Lind 1982, p. 67). Moreover, the discount rate chosen determines the impact of risk of future periods.

From the above interpretation of risk, the paper has three lines of attack: First, which are the variables of large-scale ventures that show specific variance? Second, to what extent can a single agent adjust to the variance in these variables? Third, by which measures can the risk of large-scale ventures be reduced if more than one agent is considered and what is the role of risk sharing?

Types of risks

The decision problem of a private resource firm in the case of a large-scale venture boils down to the question whether the initial financial outlay, A, can be recuperated by the present value Π of period profits which are discounted with the discount rate δ where

$$\Pi = \int_0^T e^{\delta t} \pi(t)\, dt.$$

The firm maximizes the present value of profits

$$\Omega = - A + \Pi \qquad (1)$$

subject to a set of constraints such as the finite stock of resources given, capacity constraints of production, operating cost functions etc. Typically, the firm initially chooses the level of capacity and the extraction profit over time. Nearly all the factors influencing the viability of a large-scale resource venture such as costs, demand, or the price of substitutes are associated with different degrees of uncertainty. Thus, different types of risk can be distinguished.

Financial risk. The cause of the uncertainty problem of large-scale ventures is that large-scale ventures are technically indivisible, that very often they cannot be developed step by step and that they require a huge initial outlay that is faced with the risk of being lost. The present value of profits Ω is a random variable. If the firm provides the financial outlay itself, for instance from retained earnings, the financial exposure to risk may threaten the existence of the firm if the project fails. There is a risk of financial ruin. Moreover, heavy financial exposure may impede access of the firm to financing in the future thus limiting its options for growth (Walter 1986).

The financial outlays involved in some large-scale resource projects are shown in Table 1 and 2.

Table 1. Setup Costs for Large-Scale Energy Ventures (in billion U.S. dollars)

Project	Location	Setup Costs	State of the Project
Alaska Gas Pipeline 4800 miles	Alaska Midwest	40-50	Planned but shelved
German/Russian Gas Pipeline 3600 miles	West Siberia-Rep.of Germany	15	Under construction
Athabasca (Tarsands)	Alberta, Canada	13	Cancelled during planning phase
Woodside (Gas)	Northwest Shelf, Australia	11.9	Producing
Liquified Natural Gas	Nigeria-France	10	Planned
Rundle (Shale Oil)	Australia	10	Cancelled during planning phase
Norway Gas Deal	North Sea	8.2	Planned
Trans-Alaska Pipeline (Oil) 789 miles	Prudhoe Bay-Valdez, Alaska	8	Constructed
Ekofisk	North Sea	6.7	Producing
Colony Shale Oil	Colorado	6	Cancelled
Northwest Dome (Gas)	Quatar	6	Planned; will be developed at lower level
Upper Zakum Oil Field	Abu Dhabi	5.5	Producing
Coal Refinement	Fed. Rep. of Germany	5.5	Planned
Trans-Canadian Pipeline (Oil)	North Slope-Chicago	5.3	Not available
Brent Field	North Sea (United Kingdom)	5.2	Producing

Project	Location	Setup costs	State of the Project
El Cerrejon Coal Mines	Columbia	3.5	Producing
Brown Coal	Hambach, Fed. Rep. of Germany	2.5	Planned
Gas Pipeline	North Sea (Statfjord-Emden)	2.3	Constructed
Gas Pipeline 1080 miles	Hasse R'Mel (Tunisia-Bologna (Italy)	2.26	Constructed
Cathedral Bluffs Project (Shale Oil)	USA	2.2	Producing
Gas Pipeline 604 miles	North Sea (Statfjord-Scotland)	2.03	Planned
Brae Field	North Sea (United Kingdom)	2	Producing
Statfjord C Oil Concrete Platform	North Sea	2	Producing
North Alwyn (Oil) Field Project	North Sea	1.83	Under construction
Coal Project	Venezuela	1.5	Planned
Tern Field	North Sea (United Kingdom)	1.47	Postponed
Beryl Field	North Sea (United Kingdom)	1.29	Producing
Roxby Downs (Uranium)	Australia	1.13	Feasibility Study

Data collected from newspaper reports and from Walter (1986) and transferred into U.S. dollars according to prevailing exchange rates.
Data verified on the basis of Financial Times International Year Book (1984), Oil and Gas 1985.

Table 2. Setup Costs for Large-Scale Ventures in Mineral Industry (in billion U.S. dollars)

Projects	Location	Setup Costs	State of the Project
Carajas (iron ore; other minerals; costs estimate including mine, township, railroad, port)	Brazil	4.9	Under construction
New aluminium smelters (including hydrology)	(Projected in several countries)	2.5-3	Planned
Titanium (5000 tons/year)	Australia	2.12	Planned
Mifergui-Nimba bauxite	Guinea	1.5	Planned
OK Tedi (Gold / Copper)	Papua New Guinea	1.32	Producing (Gold)
Aluminium Plant (500 000 tons/year)	Portland, Victoria, Australia	1.3	First stage constructed; next two stages shelved
Iron ore mining facilities	Pilbara, Western Australia	0.53	Planned
Wikuna vanadium	Australia	0.32	Planned
Cerro Matoso Nickel	Columbia	0.21	Planned
Gunning Bijeh Copper	Irian Jaya, Indonesia	0.175	Producing

The financial risk is influenced by other types of risk. Note that the classification of the types of risk used here does not prevent overlappings.

Revenue or price risk. High capital outlays and a long gestation period mandate that the product of the resource-venture is being sold in the market over a long period of time. Thus, the existence of high fixed costs implies large volumes of production in order to reduce costs per unit. The project may be faced with the risk that the product cannot be sold or that the price is uncertain. Demand may fall off at some point in time either due to a change in demand behavior or due to new sources of supply. Price may also vary cyclically (mineral resources).

Cost risk. A risk arises when operating costs vary irregularly; a foreseeable trend of cost increase, however, does not represent a risk. Examples are changes in capital costs, in wages, in freight rates and technological miscalculations leading to increased operating costs. Unforeseen environmental impacts may cause an increase in cost in a given setting of environmental policy. New regulation and additional environmental constraints imposed at a later period in the life of the mine are cases in point for a variance in costs. Cost risk may also relate to the closing costs of a mine or to the investment costs at the start when institutional restraints increase time costs for obtaining a permit.

Supply risk. Some large-scale ventures such as electricity plants require a permanent stream of inputs and thus face the risk of supply disruption.

Completion risk. The long gestation periods involved in large-scale ventures give rise to the completion risk if unforeseen technological problems arise, if the leading contractor does not deliver on time or if the process of obtaining a permit involves more time than expected. If the time schedule cannot be hold up, cost overruns will occur.

To these predominantly economic risks, technological, geological, environmental and political risks must be added.

Technological risk. When large-scale ventures duplicate known technical solutions, the technological risk is negligible (opening a new copper mine similar to one already existing). When, however, an innovation in size take place or when new technical solutions have to be found (Antarctic, Sea Bed Mining, North Sea drilling in retrospect), the technological solution may fail. Moreover, the "hard" technology component involves complex interdependencies and the possibility of failure.

Exploration and resource risk. A specific technical risk is the possibility of failure in exploration. Moreover, even when the mine is operating, the resource stock and its properties (quali-

ty) under an area of land or sea may not be well known (geological resource risk).

Environmental risk. Resource extraction tends to be pollution-intensive or may have in terms of air, land and water pollution negative environmental impacts. With large-scale ventures representing new technological approaches, not all environmental effects of resource-extraction may be apparent at the outset. Unexpected side effect may evolve during the period of resource-extraction.

Permit or acceptance risk. The externalities perceived by the policy maker or by the public influence the institutional setting of resource-extraction. For instance, in the case of backstop technologies in the industrial nations, some technologies like atomic power plants may have a low risk acceptance. A permit may not be received, the time costs of obtaining a permit may be high, and the stipulations of a permit may be changed over time. When risk acceptance remains constant over time, the large-scale venture will meet the acceptance risk very early in the planning process. A change in risk acceptance, however, will imply a change in regulations for resource-extraction and resource use that will only become apparent at a later stage of a project thus representing a risk for the large-scale venture.

Taxation and Regulatory risk. Taxes such as the corporation income tax and other business taxes influence the rate of return of

large-scale ventures. This is especially true for the taxation of extraction such as extraction license fees, resource rent taxes, and extraction taxes. A change in taxation redefines the conditions for the viability of a project. The same argument holds for a change in regulation.

Expropriation risk. Besides taxation, the property rights relating to the extraction of the resource, represent a very important determinant of large-scale investments. The property rights for resource-extraction may vary from securely defined leases auctioned off for the highest bidder via profit sharing arrangements to nationalized industries relying on foreign technological and management expertise via subcontracts (Barrows 1981).

Government risk. Finally, the government may change either by having a new party in power or by some type of a coup. In both cases, taxation and contracts may be altered.

The last three types of risk have also been summarized under the heading of political risk and if they are specific to a country as country risk. This term suggests that countries can be classified according to the constancy of their institutional setting or resource-extraction including such factors as taxation, profit sharing arrangements and stability of governments and political systems.

<u>The impact of risk for the sponsor-owner as a single agent</u>

In order to analyze the role of risk for a large-scale resource venture we first develop a frame of reference in which we assume only one agent being the sponsor, the operator and the supplier of capital in one person. Capital for instance is provided from retained earnings. Assume that this agent faces a given price risk for his resource, the risk being distributed identically and independently over time. The price risk gives rise to the risk of financial loss.

How will the single profit-maximizing agent react to risk? He will adjust the profit-maximizing control parameters of his maximization problem from equation 1 in such a way that the variance in the resource price becomes less relevant. What are some of the options available for risk reduction of the single agent?

Diversification into the future. If the price risk is distributed identically and independently over time, the firm can reduce the impact of a given variance in price on the present value of profits by shifting revenue into the future, i.e. by postponing extraction. Future revenues are less risky because they are discounted and the present value of the risky revenue is reduced. Diversification into the future becomes more interesting with a higher discount rate. Of course, this approach

is more promising if the price risk is reduced over time. If, however, the price risk rises over time, the increase in the price risk may offset the impact of discounting. Note also that a reduction in the present value of the price risk due to discounting may be overcompensated by an increase in political risk. Thus, a diversification into the future is only applicable if the risk does not increase over time. Moreover, uncertainty of a variable may arise in different periods in the life of the mine. One may be able to reduce some type of uncertainty at an early stage (geological resource availability) whereas other types of uncertainty such as environmental risk may only appear over time.

Reduction of size of investment. If the initial size of the investment is not determined by technical considerations, an increase in the variance of price would mandate a lower capacity to be used for a longer period of time. The longer duration of the use of the capacity represents a diversification into the future; the lower initial investment reduces the risk of financial loss. Again, if the price risk (or political risk) increases over time, the firm can adjust by a lower initial investment but not by a longer use of the capacity. A special case arises if the project can be partitioned into several stages. Then investment can be partly stretched into the future reducing the risk of financial loss.

Portfolio of projects. A firm may diversify its risk by undertaking projects with different risk characteristics. Thus, a high technological risk in one project may be offset by a low technological risk in another project. Or exposure to a political risk or country risk in a developing country may be compensated by a project in a country with a lower country risk.

Information and learning. Risk is due to non-existing or uncertain knowledge. The gathering of information is therefore an important method to reduce risk. Thus, geological or exploration risk can be lowered by geological studies before exploration starts. Technological risk may be reduced by similar operations on a smaller scale or by simulating the large-scale project in computer models. In the case of environmental risk, it seems a good policy to reduce unexpected externalities and to sincerely check them out at the outset of the planning process. It may also be helpful to let local groups participate in the planning process (open planning) in order to reduce the political risk of a change in regulation. Learning, i.e. accumulating experience by operating a large-scale facility, is another way to increase information. For a given level of risk, i.e. a given variance in some of the relevant variables such as price, the sponsor-owner maximizes profit by adjusting his control parameters to the given risk. Assume now that risk increases parametrically. Then the present value of profits will be affected by the level of risk. Let α represent a measure of risk such as the variance in the price of the resource or in

environmental damage. Let α increase for instance by increasing the variance in the price as a random variable for each period. Then expected period profits become less certain, and the expected present value of profits will be reduced. Thus, it is rather realistic to assume

$$\Omega(\alpha) \quad \text{with} \quad \Omega_{\alpha} < 0, \qquad \Omega_{\alpha\alpha} < 0 \tag{2}$$

Equation 2 is illustrated in Figure 1.

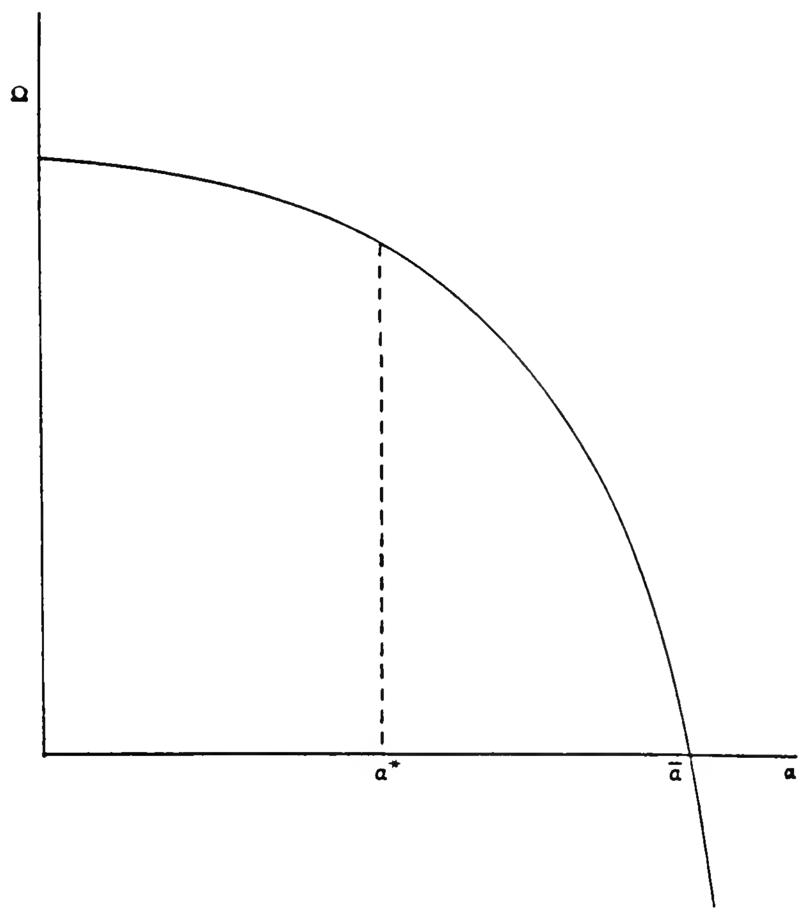


Figure 1

With risk increasing, the expected present value of profits is reduced. At a level $\bar{\alpha}$, the expected present value of profit is zero, and for $\alpha > \bar{\alpha}$, the project is not viable. In Figure 1, it has been assumed that the firm faces a given variance such as a variance of the resource price, that the set of risk policy instruments is given and that the firm maximizes the present value of profits. The firm then can reduce risk to a level α^*. Profit maximation implies that all avenues of risk reduction open to the firm are used. Note that the relation between the present value of profits and risk is also influenced by a number of parameters such as the stock of resources given, the capacity constraint and operating costs per period so that the curve shifts with these parameters.

Equation 2 being defined for a given set of risk policy instrument Γ means that a change in the policy set will enable the firm to reduce risk and thereby increase profit. The change in the policy set may be brought forward by the individual firm as an innovation, or it may be produced by variations in the institutional setting. For instance, the existence or non-existence of future markets, rules for long-run contracts or imperfections of the capital market influence the set of policy instruments relevant for the firm.

Risk shifting to a second agent

The single agent has not too many options to accomodate risk. In order to analyze how risk shifting works we now introduce a second agent, for instance a supplier of capital.

Risk reduction can be interpreted as a reduction in the variance of a random variable relevant for the maximization problem of the firm. Let $\tilde{x}$ be a random variable such as a period profit, revenue, price or cost per period and let $f(\tilde{x})$ represent the probabilities of distribution for a given period prior to the action of the firm. Risk reduction takes places if by some action of the firm the variance in the random variable is reduced so that $\tilde{x}$ is no longer relevant for the maximization problem, but now $\tilde{x}^F$ denotes the relevant random variable with a distribution function $g\ (\tilde{x}^F)$. We have

$$g\ (\tilde{x}^F) = \phi\ [\ f(\tilde{x}),\ \Gamma\ ]$$

This transformation of a relevant variable is illustrated in figure 2 where a simple linear relationship has been assumed in quadrant III.

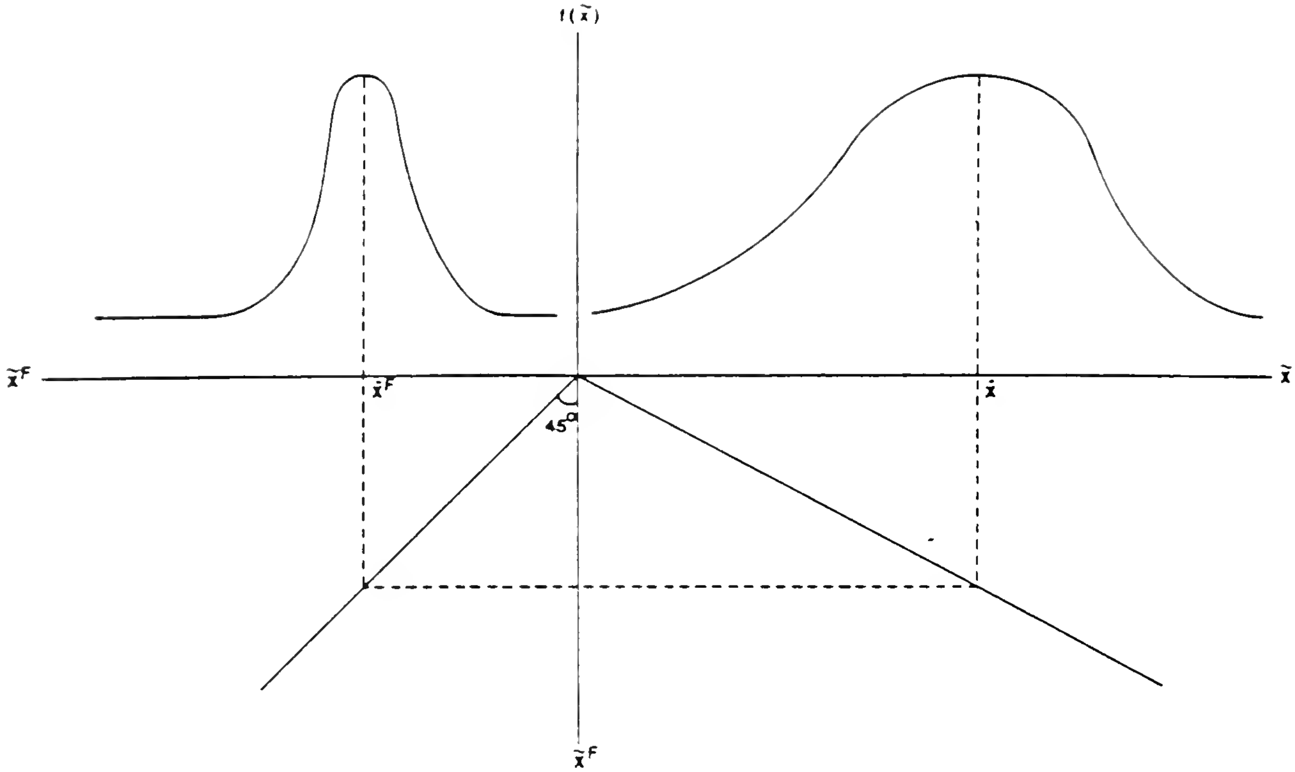


Figure 2

Thus, risk reduction can be formalized as

$$\alpha = \alpha(\Gamma) \qquad , \alpha_{\Gamma} < 0, \ \alpha_{\Gamma\Gamma} > 0 \qquad (3)$$

It is realistic to assume that applying the policy instrument Γ implies progressively rising costs with

$$v = v(\Gamma) \qquad , v_{\Gamma} < 0, \ v_{\Gamma\Gamma} > 0 \qquad (4)$$

Define profits as

$$G = \Omega \ [\ \alpha(\Gamma) \ ] - v(\Gamma), \qquad (5)$$

we have

$$dG/d\Gamma = \Omega_\alpha \alpha_\Gamma - v_\Gamma \qquad (5a)$$

and

$$d^2G/d\Gamma^2 = \Omega_{\alpha\alpha}\alpha^2_\Gamma + \Omega_\alpha \alpha_{\Gamma\Gamma} - v_{\Gamma\Gamma} < 0 \qquad (5b)$$

according to the assumptions. If G can be increased by using Γ, i.e. if $\Omega_\alpha \alpha_\Gamma > v_\Gamma$ for some Γ, risk reduction can be illustrated as in figure 3.

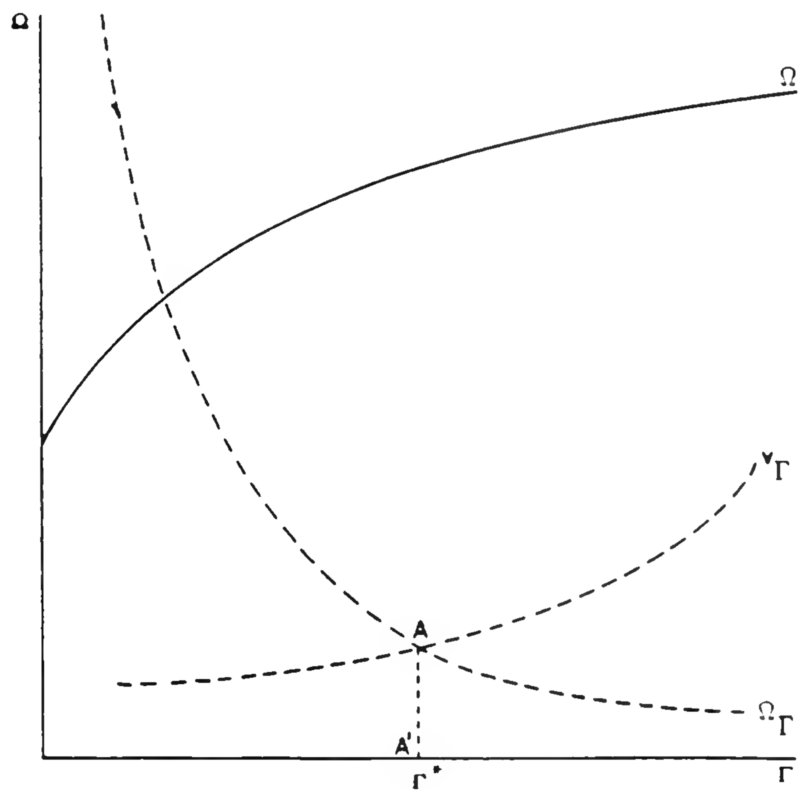


Figure 3

It is worth while for the firm to use Γ up to Γ^* in order to increase profits. Since Γ reduces risk, figure 3 associates levels of profit with risk. The Ω_Γ-curve can be interpreted as the willingness to pay curve for the shifting of risk, i.e. as a demand curve for risk shifting.

In reality, the policy instrument Γ can take a variety of specific firms. An important case in point for large-scale ventures is to limit the financial exposure of the sponsor and to shift part of the financial risk to the supplier of capital. A firm may reduce its exposure to financial loss and at the same time reduce its price risk by having a capital supplier join the venture. In the most simple case, the financier may provide a percentage β of initial financial outlays and may receive an equal percentage of period profits. Under this assumption, equation 5 can be simplified into

$$G(\beta) = (1 - \beta)\, \Omega\, [\alpha(\beta)]$$

In figure 3 let the policy instrument Γ be the percentage β defined for $0 \leq \beta \leq 1$. Then Ω_Γ in figure 3 can be interpreted as the marginal willingness of the firm to bring in foreign capital. The firm can reduce its risk and increase the present value of profits by increasing β from a zero-level, and with curves as shown in figure 3, there will be an optimal β^* with $0 \leq \beta^* \leq 1$.

In figure 2, though the probabilities for future profits of the project are not affected, the profit expected by the firm shows a different probability distribution around a lower mean due to profit sharing in a given period. For the firm, the variance of profits is reduced, and it can increase initial investment, i.e. capacity, and shorten the life-time of the mine.[1] The important contribution of equity financing consists in reducing the risk of financial loss to the individual agent; the lumpiness of a large-scale venture is reduced, at least from the financing aspects.

The basic point of risk shifting is that by shifting the risk to someone else, the producing firm can increase its profit by reducing its risk. With the risk policy variable Γ being related to the level of risk α in equation 3, the Ω_α-curve in figure 3 may also be drawn as a function of α as in figure 4. The Ω_α-curve represents the willingness to pay for the reduction of risk indicating the increase in profits per unit of risk reduction. When the firm can shift the risk free of charge, it will choose the risk level α^*. It is quite realistic that risk will be taken over only with a risk premium AA' increasing with the level of risk (curve SS). If for instance α relates to a price risk and if the demand side faces a supply risk (risk of disruption), it may be willing to pay a risk premium BB' its curve of willingness to bear risk going through B'. If the demand side is not specifically interested in a long-run contract, the resource firm may have to give up a lump sum amount AA' per unit of risk in order to induce the demand side into a long-run contract. In figure 4, both par-

ties derive benefits from risk allocation analogous to producer's and consumer's rent.

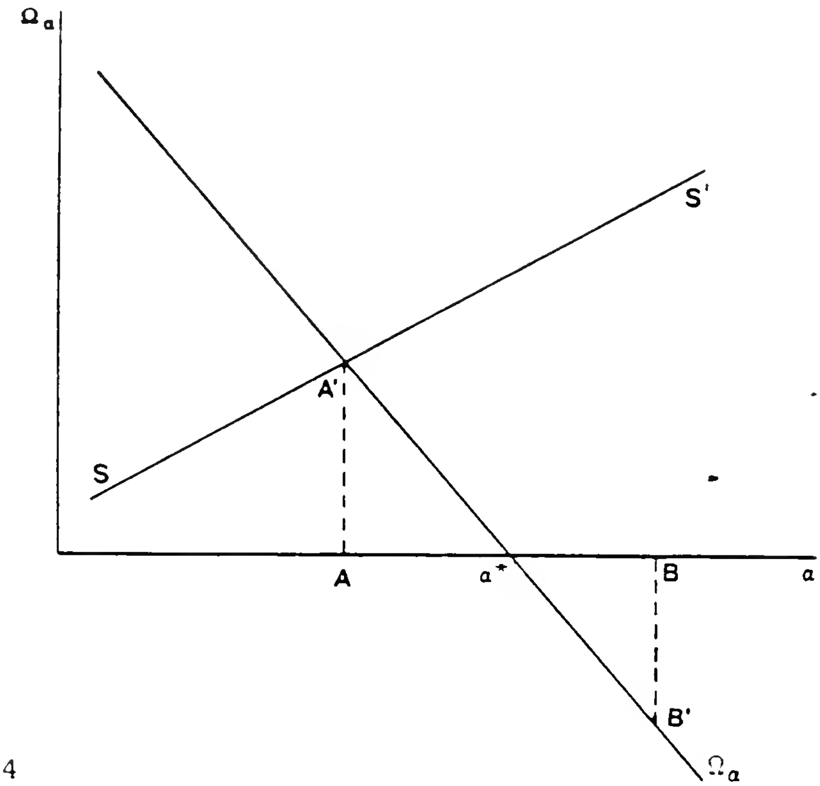


Figure 4

Risk allocation in a complex net of contractual arrangements

In reality, many agents are involved in large-scale ventures: the project operator making the investment and operational decisions, sponsors providing some of the capital, know-how and access to market, contractors responsible for construction, suppliers of inputs, banks and other financial institutions, the government defining the right to extract the resource,

granting permits of operation and specifying taxes, as well as international organizations and the customer.

The different types of risk are allocated to the different agents in a complex net of contractual arrangements. The main question for the role of risk in large-scale ventures is: How are the different types of risk allocated to the different agents involved? Which institutional arrangement allows the shifting of risk? Can these institutional arrangements reduce the risk of the main sponsor, i.e. increase his profits and make a large-scale project viable or more profitable.

In the following we review some of the most important instruments of risk shifting:
Limits on financial exposure. Financial risk can be reduced by putting a limit on financial exposure. This can be achieved by shifting the risk to equity capital as already discussed and by establishing a vehicle company separating the risk of the large-scale venture from the sponsor's balance sheet (Walter 1986). The financial risk can be further reduced by bringing in additional sponsors thus spreading the risk on many shoulders.

Shifting financial risk to banks. The project operator can reduce his financial risk through project finance. Banks provide part of the capital taking over some of the financial risk. If in some future periods the price will fall and principal and interest cannot be paid, the banks may loose part of their investment. Cofinancing

from international organizations is another way to reduce financial risk.

Supplier and customer credit. The supplier of an input may provide a credit in order to stimulate his sales, either in the case of machinery or when a large-scale venture uses a permanent stream of the input (coal in electricity generation). The customer may be willing to provide a credit to be paid off by future deliveries. In this case, customer credit is likely to be linked to a long-run sales constract.

Shifting set-up cost to the resource country. Price risk and the financial risk can be shifted by reducing initial outlays for the right to extract and then receiving only a portion of the price which is random. In theory, the price risk could be shifted by moving away from a concession with a large initial lump sum payment to production sharing, a toll per barrel contract or even a service contract. In the real world, this option of risk shifting, however, increases the political risk of a change in taxation schemes or in the contract (obsolescense bargaining, contract risk). It is therefore rather unlikely as a risk management policy. Moreover, the historical change from concession of the 1960's to the more recent forms of contracts such as the toll-per-barrel arrangement reflects a change in the property rights and in the bargaining position vis-à-vis risk assignment.

Completion guarantees. Completion risk can be reduced by completion guarantees from the leading contractor and by stand-by-letters of credit from banks (Walter 1986).

Avoiding contract risk. Contractual arrangements between resource countries and international resource firms face the risk of "obsolescence bargaining" (Vernon 1971) due to the fact that the firms are in a strong bargaining position prior to exploration and investment whereas their bargaining position is severely weakened after investment has taken place. Moreover, with revenues coming in, there is a growing pressure in the resource country to change the taxation or royalty scheme and thus to revise the contract. This danger of a change in the contract may be reduced by extraction arrangements such as toll per barrel contracts and the resource-rent tax in which the resource country takes over some of the price risk.

Long-run sales contract. Price risk can be reduced by using long-run sales contracts. In that case, the variance of the price may be completely eliminated for some quantity or at least be reduced, depending on the specifics of the sales contract. The variance for the price over the total quantity in a given period will be reduced. Future markets, though limited in time depth of one or two years, play a similar role as long-run contracts. Whereas the choice of the time profile of extraction and of the initial level of investment are at the discretion of the firm, one can see that

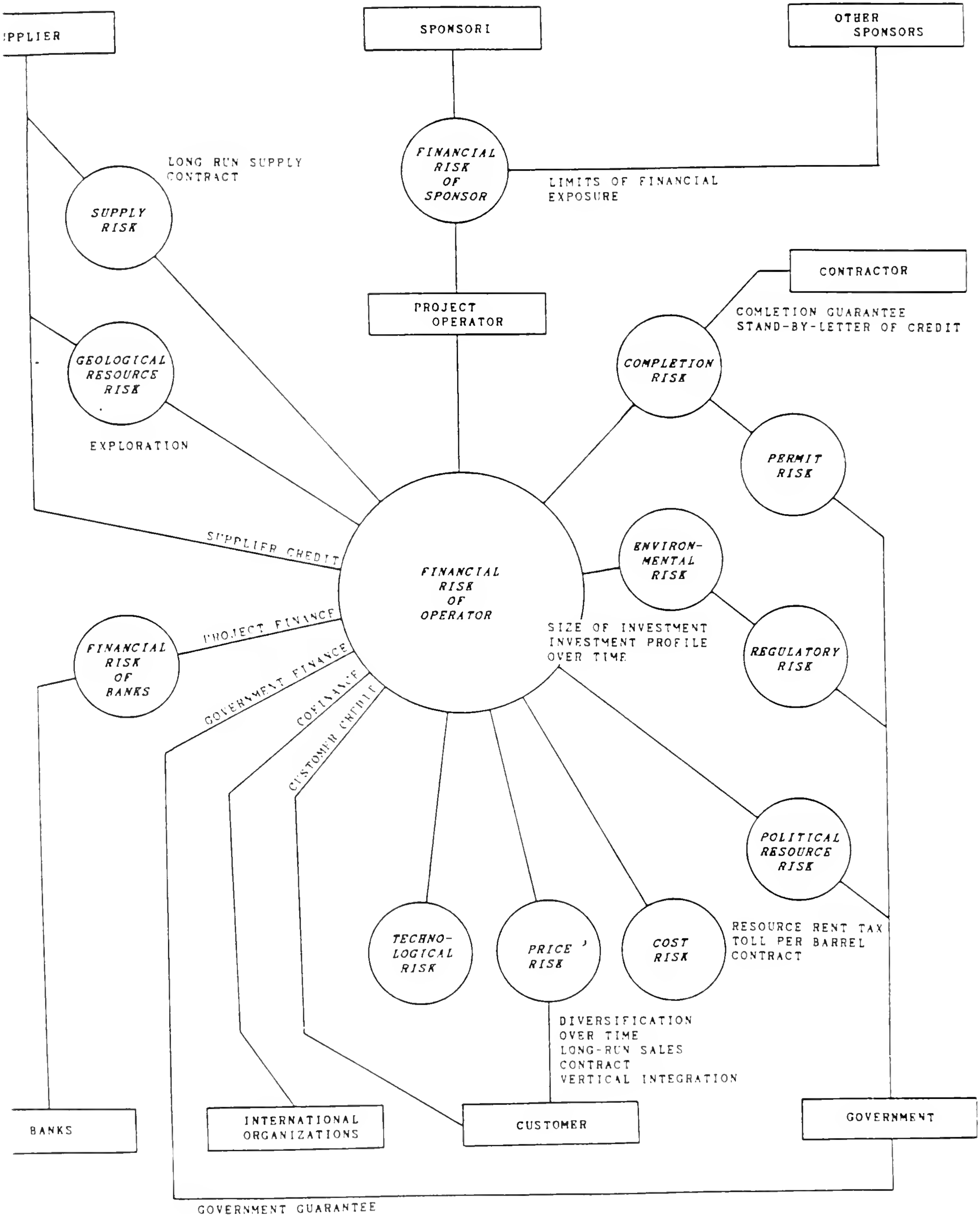
the decision on long-run contracts depends on the willingness of the partner on the demand side to enter a long-run contract.

Downstream integration. Under specific conditions, a firm may be able to reduce price risk by vertical integration. Such an approach could be followed if downstream products are less volatile in price or more specifically, if downstream activities would open up a secure line of production (chemical products in the case of an oil producing firm) whose price has a negative correlation with the oil price. Note, however, that this policy requires additional financial outlays, and though the price risk may be reduced, the risk of financial loss may rise. Of course, vertical integration may be spread over time thus allowing the reduction in the risk of financial loss.

Integrated risk management. Although the different types of separate risks mentioned above partly overlap, they may arise simultaneously thus increasing the variance in the present value of profit. The increase in the price risk, in environmental and technological risk eventually augment the variance of expected profits. Therefore, different policies of risk management may be called for simultaneously. Institutional arrangements are required that reduce several risks such as the risk of financial loss, the risk of technological failure and price risk at the same time. A case in point is the Russian German gas deal where German banks provided the financing, a German and other international steel producers delivered the pipes and other tech-

nological equipment and where a long-run sales contract reduced Russia's price risk.

Risk allocation can be interpreted as a system of contractual arrangements or a set of risk markets for the different types of risk and among different participants. The different contracts are interlinked in the sense of a general equilibrium model. Successfully shifting completion risk to the leading contractor implies a reduction in financial risk and may have an impact on financing. Allocating the price risk to the customer or to a government also reduces financial risk and requires lower risk premiums to be paid to banks. Figure 5 shows the most important agents, the different types of risk and some approaches to risk reduction.



PPLIER
SPONSORI
OTHER SPONSORS
FINANCIAL RISK OF SPONSOR
LIMITS OF FINANCIAL EXPOSURE
LONG RUN SUPPLY CONTRACT
SUPPLY RISK
PROJECT OPERATOR
CONTRACTOR
COMLETION GUARANTEE
STAND-BY-LETTER OF CREDIT
COMPLETION RISK
GEOLOGICAL RESOURCE RISK
EXPLORATION
PERMIT RISK
SUPPLIER CREDIT
FINANCIAL RISK OF OPERATOR
ENVIRON-MENTAL RISK
PROJECT FINANCE
SIZE OF INVESTMENT
INVESTMENT PROFILE OVER TIME
REGULATORY RISK
FINANCIAL RISK OF BANKS
GOVERNMENT FINANCE
COFINANCE
CUSTOMER CREDIT
POLITICAL RESOURCE RISK
TECHNO-LOGICAL RISK
PRICE RISK
COST RISK
RESOURCE RENT TAX
TOLL PER BARREL
CONTRACT
DIVERSIFICATION
OVER TIME
LONG-RUN SALES
CONTRACT
VERTICAL INTEGRATION
BANKS
INTERNATIONAL ORGANIZATIONS
CUSTOMER
GOVERNMENT
GOVERNMENT GUARANTEE

Figure 5

Figure 5 suggests that relatively high transaction costs are involved in organizing the contractual arrangements between the multitude of agents involved. With markets for allocating the risks not clearly established some international banks provide project financing as a financial package or an integrated risk management (Walter 1986).[2)]

The limits of risk shifting

Figure 4 indicates how a specific risk is allocated between two agents, and figure 5 illustrates a net of contractual arrangements and risk allocation among a multitude of agents. There are, however, limits to risk shifting and to institutional innovations that allow to shift risk more efficiently. Risk shifting is not possible if the willingness to pay for the shifting of risk and the willingness to take over risk against a premium do not match. Risk shifting can only occur if the parties involved all derive a benefit from it. There must be a rent for the demand side in the sense that not the total willingness to pay for shifting a risk is required as payment in a contractual arrangement. And there must be a rent for the supply side in the sense that the risk premium paid is higher than the internal costs of accepting the risk.

Consider figure 4. Risk shifting is not possible if the two curves do not intersect. In Figure 4, the variance in a variable is assumed given and the question is studied how the given risk can be shifted. Increase now the risk of a project parametrically, for instance its price variance. Then, the profit curve in figure 1 shifts downward implying a lower α^*, i.e., the willingness to pay is definitely reduced for $\alpha \geq \alpha^*$. If the parametrically increased risk does not imply a larger gain in profit with a unit of risk shifted, the willingness to pay curve in figure 4 will shift to the left, and risk shifting becomes less likely. A similar result holds if the producing firm has a higher risk aversion.

If the willingness to accept risk against a premium is reduced, the SS-curve in figure 4 will shift upward making a market clearing risk allocation less likely. Such a situation arises if the supplier of risk bearing is facing less favorable restraints which allow him to take over only a lower level of risk or if he becomes more risk averse.

Private risk and social risk may diverge. In such a case, a resource project may not take into account all risks that accrue to society. Consider for instance the case of environmental risk which due to existing and anticipated regulation is not included in the profit calculus of a firm. From the point of view of the firm it shifts the risk to the public, and risk allocation for society as a whole is not optimal. So in risk allocation and risk

shifting, risks related to an externality should be internalized. Social risk cannot be shifted, but it can be reduced by the agent to whom it is attributed. Take the risk of environmental disruption. Environmental quality being a public good, there is by definition no way to reduce the risk by shifting it to another person. Only if the assumption of a public good is given up and a regional dimension of public goods is introduced, can risk of different regional public goods be pooled. Note, however, that social risk, when properly internalized, can be reduced by internal measures of a firm, i.e. by pollution abatement.

Conclusions

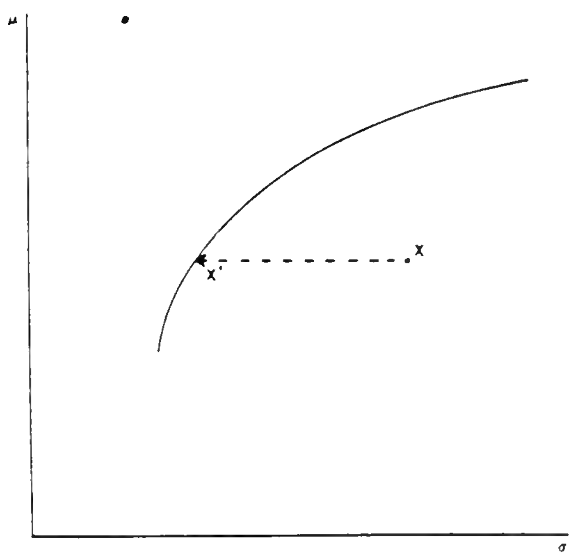
The viability of a large-scale venture is reduced by the existence of a variety of risks such as price risk, technological risk, and environmental risk. All these different types of risk make expected profit a random variable and give rise to the possibility that the huge initial financial outlay necessary for setting up a large-scale venture may be lost. Some of these risks may be reduced by internal adjustments such as the time profile of extraction or the level of initial investment, and some of the risks may be shifted. A demand curve for the shifting of risk is derived. The resulting risk allocation depends on such factors as the risk attitudes, the amount of variance initially given and the options available to the firm and the supplier of risk bearing to reduce and transform the risk internally. In reality, many agents are

involved and risk allocation must be understood as a complex net of contractual arrangements. Private and social risks of a large-scale venture may diverge, and social risk should be internalized so that social risks are reduced by internal adjustments of the firm. Social risks, however, cannot be shifted.

Footnotes

* Paper to be presented at the "Global Infrastructure Fund" workshop on "Global Infrastructure Projects", Anchorage. I am grateful for critical comments by J. Keck and J.E. Parsons.

1) In the familiar μ-σ-diagram, project financing reduces σ for the individual agent, thus shifting the position of portfolio X (efficient prior to the innovation of project financing) to the left (X') and allowing a new transformation space between μ and σ as shown in the diagram (Agmon, Lessard and Paddock, 1979, p. 305).



2) Note that project financing and the lumpiness of large-scale ventures represent an argument for compensatory trade as a specific aspect of a financial package which the market may not be able to provide.

References

Agmon, T., Lessard, D. and Paddock, J.L. (1979), Financial Markets and the Adjustment to Higher Oil Prices, in R. S. Pindyck (ed.), Advances in The Economics of Energy and Resources, Greenwich, Conn., 291-310.

Barrows Inc. (1981) World Petroleum Arrangements 1980 Vol. II, New York.

Brennan, J.M. and Schwartz, E.S. (1985), Evaluating Natural Resource Investments, Journal of Business, 58, 135-157.

Financial Times International Year Book (1984), Oil and Gas 1985, Longman, Old Woking, Surrey.

Garnaut, R. and Clunies Ross, A. (1983). Taxation of Mineral Rents. Oxford: Clarendon Press.

Leland, G.C. (1978), "Optimal Risk Sharing and Leasing of Natural Resource, with Application to Oil and Gas Leasing on the OCS", Quarterly Journal of Economics, Vol. 42, 413-438.

Lind, R.C. (1982), A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options, in R.C. Lind et al. (eds.) Discounting for Time and Risk in Energy Policy, Baltimore, London, John Hopkins University Press, 21-94.

Long, N.V. (1984), "Risk and Resource Economics: The State of Art", in: Risk and the Political Economy of Resource Development, ed. by Pearce, D.W. / Siebert, H. / Walter, I.; New York 1984, 59-73.

Miller, M.H. and Upton, C.W. (1985), A test of the Hotelling Valuation Principle, Journal of Political Economy, 93; 1-25.

Palmer, K.F. (1980), Mineral Taxation Policies in Developing Countries: An Application of Resource Rent Tax. IMF Staff Papers 27, 517-542.

Pearce, D.W. (1984) et al., Risk and the Political Economy of Resource Development, London: MacMillan.

Pindyck, R.S. (1980), Uncertainty and Exhaustible Resource Markets, Journal of Political Economy, 88; 1203-25.

Pouliquen, L. (1979), Risk Analysis in Project Appraisal, Baltimore.

Reutlinger, S. (1980), Techniques for Project Appraisal under Uncertainty, Baltimore.

Samuelson, P.A. (1954), "The Pure Theory of Public Expanditure", Review of Economics and Statistics 36, 387-389.

Siebert, H. (1984), "The Economics of Natural Resource Ventures", in: D.W. Pearce et al., eds., Risk and the Political Economy of Resource Development, London: MacMillan.

Vernon, R. (1971), Sovereignty at Bay. The Multinational Spread of U.S. Enterprises, New York.

Walter, I. (1986), Financing Natural Resource Projects, Mimeo, Fontainebleau, New York.

Wilson, R. (1982), Risk Measurement of Public Projects, in R.C. Lind (Ed.), Discounting for Time and Risk in Energy Policy, Washington DC, 205-249.

Date Due

DEC 19 1989